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For. **SEMICONDUCTOR OPTICAL DEVICE APPARATUS**

VERIFIED TRANSLATION OF PRIORITY DOCUMENT

Commissioner for Patents
Washington, D.C. 20231

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Sir:

Enclosed is a verified English-language translation of priority document JP 11-076421. The enclosed document is referenced in the concurrently submitted Response under 37 C.F.R. § 1.111.

Respectfully submitted,

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Attachment: Verified English-language Translation of Priority Document JP 11-076421

DECLARATION

I, Junji Kamata, Patent Attorney, of SIKs & Co., 8th Floor, Kyobashi-Nisshoku Bldg., 8-7, Kyobashi 1-chome, Chuo-ku, Tokyo 104-0031 JAPAN hereby declare that I am the translator of the certified official copy of the documents in respect of an application for a patent filed in Japan on March 19, 1999 under Patent Application No. 076421/1999 and that the following is a true and correct translation to the best of my knowledge and belief.

Dated: November 22, 2002

Junji KAMATA

PATENT OFFICE

JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this office.

Date of Application: March 19, 1999

Application Number: Patent Application No. (Hei) 11-076421

Applicant(s): Mitsubishi Chemical Corporation

March 3, 2000

Takahiko KONDO

Commissioner, Patent Office

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[Document Name] Specification

[Title of the Invention] Semiconductor Light Emitting Apparatus

[Clams]

1. A semiconductor light emitting apparatus, at least comprising on a substrate:

a compound semiconductor layer containing an active layer;

a protection film having an opening formed on the compound semiconductor layer;

a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the opening; and

an electrode formed on the ridge type compound semiconductor layer,

and further comprising a layer whose In compound crystal composition is no less than 5%,

wherein an In compound crystal composition of the ridge type compound semiconductor layer is no more than 10%.

2. The semiconductor light emitting apparatus according to claim 1, wherein the compound semiconductor layer containing the active layer includes a first conductivity type clad layer formed below the active layer having a smaller refractive index than the refractive index of the active layer, and a second conductivity type first clad layer formed on the active layer having a smaller refractive index than the refractive index of the active layer.

3. The semiconductor light emitting apparatus according to claim 2, wherein the In content of the second conductivity type first clad layer is 5 % or less.

4. The semiconductor light emitting apparatus according to claim 2 or 3, wherein at least one layer among the first conductivity type clad layer, the active layer, and the second conductivity type first clad layer is made of a compound represented by $(Al_xGa_{1-x})_yIn_{1-y}P$ $[0 \leq x \leq 1, 0.05 \leq y \leq 1]$.

5. The semiconductor light emitting apparatus according to any one of claims 1 to 4, wherein the ridge type compound semiconductor layer contains the second conductivity type second clad layer.

6. The semiconductor light emitting apparatus according to claim 5, wherein the second conductivity type second clad layer has a refractive index in a range of $\pm 0.2$of the refractive index of the second conductivity type first clad layer, and wherein the ridge type compound semiconductor layer has a composition different from that of the second conductivity type first clad layer.

7. The semiconductor light emitting apparatus according to any one of claims 1 to 6, wherein the opening is in a stripe shape and wherein the width of the stripe is narrower at an opening end than at an opening center.

8. The semiconductor light emitting apparatus according to any one of claims 1 to 6, wherein the opening is in a stripe shape and wherein the width of the stripe is wider at an opening end than at an opening center.

9. The semiconductor light emitting apparatus according to any one of claims 1 to 8, wherein the surface of the substrate has an off-angle with respect to a lower plane direction.

10. The semiconductor light emitting apparatus according to any one of claims 1 to 9, wherein a far field pattern has a single peak.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

This invention relates to a semiconductor light emitting device such as semiconductor lasers and, more particularly, to a semiconductor laser having a ridge type stripe structure with stable laser property and high reliability of laser operation.

[0002]

[Description of Prior Art]

A structure so-called as a ridge waveguide type is frequently used to easily produce semiconductor light emitting apparatuses. Fig. 4 shows a manufacturing method for such a structure. First, an n-type clad layer 402, an active layer 403, a p-type clad layer 404, and a p-type contact layer 405 are formed on a substrate 401. Subsequently, a photoresist 411 having stripe openings as a pattern made by photolithography is formed on a wafer surface to form a stripe-shaped ridge by a wet etching process using the photoresist as a mask so that the p-clad layer 404 remains with a prescribed thickness. An insulation film 409 having insulating property is formed on the whole wafer surface; the insulation film at a top of the ridge is removed by photolithography; and an epitaxy side electrode 407 and a substrate electrode 408 are formed. The ridge structure thus formed can make the transverse mode for laser oscillation stabilized and can reduce the threshold currents.

[0003]

However, with such a conventional manufacturing method for ridge waveguide type semiconductor light emitting apparatus, because the ridge portion is formed by an etching, it is difficult to control the thickness of the clad layer in a non-ridge portion 410 with high accuracy. As a result, slight differences in the thickness of the clad layer in the non-ridge portion make the effective refractive index greatly deviated at that portion, thereby making the laser property of the semiconductor light emitting apparatus deviated and improvements in product yields not easily obtainable.

[0004]

To solve such a problem, a method has been proposed in which the thickness of the

clad layer of the non-ridge portion is determined using a crystal growth rate during the crystal growth, in which a protection film is formed at the non-ridge portion, and in which the ridge portion is re-grown (see generally, JP-A-5-121,822, JP-A-9-199,791, JP-A-10-326,934~938, JP-A-10-326,945). Fig. 3 shows producing method and structure for such a laser device. When the ridge portion is formed, a layer is selectively re-grown in using a protection film 306 as a mask on stripe shaped openings 307, and a p-type second clad layer 308 and a p-type contact layer 309 are sequentially accumulated with trapezoid cross-sectional shapes according to isotropic nature in the growth rate with respect to face orientation. With this method, the thickness of the p-type first clad layer 304 in the non-ridge portion was controlled with high accuracy, so that the effective refractive index was controlled easily.

[0005]

Because lattice matching should be made to the substrate, the In content of the respective layers of the double hetero structure including a first conductivity type clad layer, an active layer, and a second conductivity type first clad layer, like InGaAsP/In(AlGa)AsP/InP based and InGaAs/In(AlGa)As/InP based, which are formed on an InP substrate, and InGaP/IN(AlGa)P based and InGaAs/InGaAsP/InGaP based, which are formed on a GaAs substrate, is designed to have 50 % or more. In general, the In content is determined to be a necessary composition to match the lattice for the substrate whereas the Al and Ga content is determined to be a necessary composition to adjust the refractive index and the size of the bandgap.

[0006]

For example, as shown in Fig. 6, for an (AlGa)InP based red visible light laser (600 nm band) produced on a GaAs substrate, the In content is set about 50 % of the entire III group as to make the lattice matching of the active layer and the clad layer substantially with the substrate, and the refractive index and the bandgap are adjusted by setting the Al content in the active layer to be small (generally, Al content is 0 %) whereas the Al content in the clad layer to be large (generally, Al content is 30 to 50 %). To improve the laser property recently, a quantum well active layer is frequently strained, and in such a situation, the In content is generally varied between 40 % and 60 %.

[0007]

In also JP-A-9-199,791, a layer containing In (InP clad layer) is grown at the re-growth of a ridge portion at the where the double hetero structure made of a first conductivity type clad layer, an active layer, and a second conductivity type first clad layer is structured of an In(AlGa)AsP/InP based material.

When the layer containing In is selectively grown to form the ridge shape at the protection film opening, growth rate and compound crystal composition of the layer d positing

on the ridge region are easily shifted largely due to the ratio of the protection film opening width to the protection film masked region width, the growth conditions (such as substrate temperature and V/III ratio, etc.), and the like. This reason we think is illustrated by that In is readily separated particularly on the protection film or the like since In has a higher vapor pressure in comparison with Ga and Al. In a meantime, to suppress compound depositions (particularly compounds including Al) on the protection film, methods to add HCl gas in a small amount during an organic metal vapor deposition growth have been known as in JP-A-5-502147, JP-A-7-297134, etc. However, JP-A-7-297134 sets forth that the supplying molecular ratio HCl / (Al + In) should be the smallest as much as possible because the In containing amount in the film greatly depends on the supplying molecular ratio of HCl to In and because the composition of the compound crystal containing In to which HCl is added is hardly controlled as to reproduce the composition. Thus, the growth conditions in a layer containing In are severely restricted. Generally, as the In content of the double hetero structure is made higher, the In content in the ridge portion becomes higher, and as the In content in the ridge portion becomes higher, the above problem becomes more serious, and the absolute value of the change amount of the In content in the ridge portion we think becomes larger (i.e., amounts such as of the refractive index, lattice constant become larger).

[0008]

Thus, if a compound semiconductor layer (e.g., a clad layer or the like) of the re-growth portion containing In richly to some extent is to be grown, the growth rate and the composition of the compound crystal containing In are changed, thereby rendering reproduction of the prescribed ridge shape and refractive index worse, and possibly deviating the laser property (e.g., threshold current, divergence angle, etc.) of the ridge waveguide type laser. Shifts in the composition of the compound semiconductor layer containing In may cause changes in the lattice constant, bring occurrences of transfer on the boundaries of the ridge re-growth, and greatly lower the reliability on the laser operation.

Where the width of the ridge opening is made wider or narrower at the apparatus end than at the apparatus center, the near field pattern at the end facet, or namely, the beam divergence angle (emitting angle) is changeable. However, when the opening width is changed around the end where the layer containing In is grown to be in a ridge shape, the composition of the compound semiconductor layer containing In may be shifted between an apparatus center and a position near the end because the ratio of the protection film opening width to the protection film masked region width is changed, thereby raising problems of lowering controllability of beam divergence angle (emitting angle) and reproduction property

[0009]

To improve recording density of media such as a digital video disc as a center, a

visible laser (generally, 630 to 690 nm) using an AlGaInP based material starts used practically as a light source for information processing instead of the conventional AlGaAs (wavelength is around 780 nm), but the following researches have been made to realize shorter wavelength, lower threshold, and high temperature operation.

In a production of an AlGaInP/GaInP based visible laser device, use of a substrate having an off-angle from the (100) plane toward the [011] direction (or [0-1-1] direction) allows to prevent the band gap from narrowing due to formation (ordering) of natural super lattices, thereby rendering the wavelength shorter readily, facilitating high concentration doping of p-type dopants (e.g., Zn, Be, and Mg), and improving the oscillation threshold current of the device by enhancement of the hetero-barrier and temperature characteristics. If the off-angle is too small, step bunching appears outstandingly, and large undulations are formed at the hetero-boundaries, so that a shift amount in which the PL wavelength (or oscillation wavelength) is shortened by quantum effects to the bulk active layer may be smaller than the designed amount where a quantum well structure (GaInP well layer of about 10 nm or less) is manufactured. If the off-angle is made lager, the step bunching is reduced, and the hetero-boundaries become flat, thereby making the wavelength shorter by the quantum effect as designed. Thus, a substrate having an off-angle of 8 to 16 degrees from the (100) plane toward the [011] direction (or [0-1-1] direction) is generally used to suppress formation of natural super lattices and generation of step bunching, which impede the wavelength from becoming shorter, as well as to suppress the oscillation threshold current from increasing due to shortened wavelength from p-type high concentration doping and impairment of temperature characteristics. A proper off-angel should be selected in consideration of thickness and the stress amount of the GaInP well layer depending on the targeted wavelength such as 650 nm or 635 nm.

[0010]

[Problems to be solved by the Invention]

Various technologies have been developed so far as described above, but the ridge waveguide type semiconductor light emitting apparatus in utilizing In still has a room to be improved, and waits for developments of improved technology. It is an object to provide a better semiconductor light emitting apparatus capable of solving the problems on the prior art as described above. That is, it is an object of the invention to provide a semiconductor light emitting apparatus having good controllability and reproduction property of the ridge shape and the compound crystal composition (lattice constant, refractive index, etc.) of the semiconductor layer constituting the ridge with stable laser property and highly reliable laser operation.

[0011]

[Means for solving the Problems]

The inventors, as a result of diligent research to solve the above problems, found out that a semiconductor light emitting apparatus can be made with improved controllability and reproduction property of the ridge (mesa) shape and the compound crystal composition (lattice constant, refractive index, etc.) of the semiconductor layer constituting the ridge as well as improved stability of laser property and reliable laser operation thereof where designing the apparatus to include at least a compound semiconductor layer containing an active layer on a substrate, a protection film having an opening formed on the compound semiconductor layer, a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the opening, and an electrode formed on the ridge type compound semiconductor layer, and further including a layer whose In compound crystal composition is no less than 5%, wherein an In compound crystal composition of the ridge type compound semiconductor layer is no more than 10%, and they came to provide this invention.

[0012]

That is, this invention provides a semiconductor light emitting apparatus, at least comprising on a substrate: a compound semiconductor layer containing an active layer; a protection film having an opening formed on the compound semiconductor layer; a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the opening; and an electrode formed on the ridge type compound semiconductor layer, and further comprising a layer whose In compound crystal composition is no less than 5%, wherein an In compound crystal composition of the ridge type compound semiconductor layer is no more than 10%.

[0013]

That is, in the semiconductor light emitting apparatus according to this invention, the compound semiconductor layer containing the active layer preferably includes a first conductivity type clad layer formed below the active layer having a smaller refractive index than the refractive index of the active layer, and a second conductivity type first clad layer formed on the active layer having a smaller refractive index than the refractive index of the active layer. Preferable are: an embodiment in which the In content of the second conductivity type first clad layer is 5 % or less; an embodiment in which at least one layer among the first conductivity type clad layer, the active layer, and the second conductivity type first clad layer is made of a compound represented by $(Al_xGa_{1-x})_yIn_{1-y}P$ [$0 \leq x \leq 1$, $0.05 \leq y \leq 1$]; an embodiment in which the ridge type compound semiconductor layer contains the second conductivity type second clad layer; an embodiment in which the second conductivity type second clad layer has a refractiv index in a range of $\pm 0.2$of the refractive index of the second conductivity type first

clad layer and in which the ridge type compound semiconductor layer has a composition different from that of the second conductivity type first clad layer; an embodiment in which the opening is in a stripe shape and wherein the width of the stripe is narrower at an opening end than at an opening center; an embodiment in which the opening is in a stripe shape and wherein the width of the stripe is wider at an opening end than at an opening center; an embodiment in which the surface of the substrate has an off-angle with respect to a lower plane direction; and an embodiment in which a far field pattern has a single peak.

[0014]

As desirable embodiments of the semiconductor light emitting apparatus according to the invention, exemplified are: an embodiment in which the ridge type compound semiconductor layer is a compound represented by $Al_xGa_{1-x}As$ $[0 \le x \le 1]$ or $Al_xGa_{1-x}As_yP_{1-y}$ $[0 \le x \le 1, 0 \le y \le 1]$; an embodiment in which no electrode is formed on side surfaces of the ridge, an embodiment in which the width of the opening end is no less than 0.5 micron meter and no more than 1000 micron meters, an embodiment in which a distance between the active layer and the protection film is no less than 0.2 micron meter and no more than 0.5 micron meter, an embodiment in which a contact layer is formed as to cover substantially the whole surface of the ridge type compound semiconductor layer, an embodiment in which at least one layer constituting the ridge type compound semiconductor layer contains Al, an embodiment in which a gas containing halogen element or elements is added in a small amount when the ridge type compound semiconductor layer is selectively grown in use of the organic metal vapor deposition growth at the protection film opening, an embodiment in which the opening is so selected to extend in a direction that the contact layer is formed as to cover substantially the whole surface of the ridge type compound semiconductor layer, an embodiment in which a crystal growth plane of the substrate is (100) plane or its crystallographically equivalent plane and in which an extending direction of an opening of the protection film is [01-1] direction or its crystallographically equivalent direction, an embodiment in which a part of the ridge type compound semiconductor layer overlaps on the protection film, an embodiment in which the refractive index of the active layer is smaller than the refractive index of the protection film, an embodiment in which the active layer is constituted of a single or plural quantum well layers and optical guide layers; an embodiment in which the anti-oxidation layer is formed on the second conductivity type first clad layer and formed at least at the opening of the protection film.

[0015]

[Embodiments of the Invention]

Hereinafter, referring to d tails of respective layers and an example of the manufacturing process, a semiconductor light emitting apparatus according to the invention is

described specifically.

The semiconductor light emitting apparatus according to the invention at least includes, on a substrate, a compound semiconductor layer containing an active layer, a protection film having an opening formed on the compound semiconductor layer, a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the opening, and an electrode formed on the ridge type compound semiconductor layer.

The substrate used for the semiconductor light emitting apparatus according to the invention is not specifically limited as far as allowing a double hetero structure crystal to grow on the substrate. What is preferable is a conductive material, and desirably, the substrate is a crystal substrate made of, e.g., GaAs, InP, GaP, ZnSe, ZnO, Si, and Al_2O_3 suitable for growth of a crystal thin film on the substrate, more preferably, a crystal substrate having a zinc-blende structure. The crystal growth surface on the substrate is a low degree crystallographic plane or a crystallographically equivalent plane, more preferably a (100) plane. In this specification, "(100) plane" is not necessary to be strictly a just (100) plane and can encompass cases that the substrate has an off-angle of 30° at most. In regard with the scale of the off-angle, the upper limit is preferably 30° or less, more preferably 16° or less, whereas the lower limit is preferably 0.5° or greater, more preferably 2° or greater, further preferably 6°or greater, and most preferably 10° or greater.

The substrate may be a hexagonal system substrate, and in such a case, Al_2O_3, 6H-SiC, etc. can be used.

[0016]

The compound semiconductor layer containing an active layer, formed on the substrate, generally includes a layer in which the In compound crystal composition is no less than 5%. The compound semiconductor layer generally includes a layer having a refractive index smaller than that of the active layer on each of upper and lower sides of the active layer. A layer on the substrate side functions as a first conductive type clad layer, and a layer on the other side, or the epitaxial side, functions as a second conductive type first clad layer. The compound semiconductor layer may contain a layer functioning as an optical guide layer.

The layer having an In composition crystal content of 5 % or higher can be any of the layers constituting the compound semiconductor layer. Preferable one is at least a layer among the first conductive type clad layer, the active layer, and the second conductive type first clad layer. Particularly, the In content of the compound crystal of the second conductive type first clad layer is preferably 5 % or higher. The composition of the layer that the In content of the compound crystal is 5 % or higher is preferably $(Al_xGa_{1-x})_yIn_{1-y}P$ [$0 \le x \le 1$, $0.05 \le y \le 1$]. A higher average value of the In contents of the entire compound s miconductor layers is

preferred. More specifically, it is preferable 5 % or higher, more preferably 15 % or higher, and further more preferably 30 % or higher.

[0017]

The ridge type compound semiconductor layer containing the layer having a smaller refractive index than that of the active layer formed on the stripe shaped opening is generally made of a second conductive type second clad layer as a major portion. The compound semiconductor may contain a layer functioning as, e.g., an optical guide layer, other than the second conductive type second clad layer. The substantially whole surface of the surface is preferably covered with a contact layer having a low resistance.

The clad layer, the active layer, and the contact layer are not specifically limited, but it is preferable to use a general group III-V or II-VI semiconductor such as AlGaAs, AlGaInAs, AlGaInP, GaInAsP, AlGaInN, BeMgZnSe, MgZnSSe, and CdZnSeTe, and to produce a double hetero structure in which the active layer is sandwiched by the two clad layers. As a clad layer, a material having a smaller refractive index than that of the active layer is selected, and as a contact layer, a material having a narrower band gap than that of the clad layer is selected. As a proper carrier density of a low resistance to gain an ohmic contact with electrodes, the lower limit is preferably $1 \times 10^{18}\ cm^{-3}$ or greater, more preferably, $3 \times 10^{18}\ cm^{-3}$ or greater, most preferably, $5 \times 10^{18}\ cm^{-3}$ or greater. The upper limit is preferably $2 \times 10^{20}\ cm^{-3}$ or less, more preferably, $5 \times 10^{19}\ cm^{-3}$ or less, most preferably, $3 \times 10^{19}\ cm^{-3}$ or less. The active layer is not limited to a single layer and can be a single quantum well structure (SQW) composed of a quantum well layer and optical guide layers vertically sandwiching the quantum well layer or a multiple quantum well structure (MQW) composed of plural quantum well layers, barrier layers sandwiched between the quantum well layers, and optical guide layers respectively formed on the uppermost quantum well layer and under the lowermost quantum well layer.

[0018]

The protection film is not specifically limited but it is necessary to provide insulating property to confine currents with the protection film on both sides of the opening so as to perform current injections only to a region of the active layer located below the ridge portion, which is formed on the opening of the protection film, and also the refractive index of the protection film is preferably smaller than that of the compound semiconductor layer of the ridge portion, or more specifically, of the second conductivity type second clad layer to give effective refractive index difference between the ridge portion and the non-ridge portion in a transverse direction in the active layer and to stabilize the transverse mode of the laser oscillation. However, as a practical matter, if the refractive index difference is too large between the protection film and the second conductivity type second clad layer of the ridge portion, the first clad layer below the ridge has to be thicker because the effective refractive index step in the

transverse direction tends to be larger in the active layer, thereby increasing leak currents in the transverse direction. To the contrary, if the refractive index difference is too small between the protection film and the second conductivity type second clad layer of the ridge portion, the protection film has to be formed thicker to some extent since the light easily leaks outside the protection film, but this tends to impair the cleavage property. In consideration of those, together, the lower limit of the refractive index difference between the protection film and the second conductivity type second clad layer of the ridge portion is 0.3 or greater, more preferably, 0.2 or greater, and most preferably, 0.5 or greater. The upper limit is 3.0 or less, more preferably, 2.5 or less, and most preferably, 1.8 or less. There would be no problem, in regard with the thickness of the protection film, as far as the protection film can show a sufficient insulation property and has a thickness such that light does not come outside the protection film. The lower limit of the protection film is preferably 10 nm or greater, more preferably, 30 nm or greater, and most preferably, 50 nm or greater. The upper limit is preferably 500 nm or less, more preferably, 300 nm or less, and most preferably, 200 nm or less.

[0019]

The protection film is preferably a dielectric, and more specifically, can be selected preferably from a group of SiN_x film, SiO_2 film, SiON film, Al_2O_3 film, ZnO film, SiC film, and amorphous Si film. The protection film is used as a mask for formation of the ridge portion through a re-growth using an MOCVD method and is also used for the purpose of current squeezing. For simplifying the process, it is preferable to use a film having the same composition commonly for current squeezing and for selective growth, but layers having different compositions may be formed as a multilayer when necessary.

Where a zinc-blende type substrate is used and where the substrate surface is a (100) plane or its crystallographically equivalent plane, it is preferable that the longitudinal direction of the stripe shaped opening (the extending direction of the stripe) is extending in a [01-1] direction or its crystallographically equivalent direction to readily grow a contact layer, as described below, on the ridge top and the side surface. At that time, the most portion of the ridge side surface becomes (311)A plane in many cases, and it is possible to grow a contact layer on substantially the whole surface, on which a layer can be grown, on the second conductive type second clad layer forming the ridge. This tendency is particularly remarkable when the second conductive type second clad layer is AlGaAs, particularly, AlGaAs having an AlAs content of 0.2 to 1.0, preferably, 0.3 to 0.9, more preferably, 0.4 to 0.8. The off-angel direction may be preferably within ± 30° from a direction perpendicular to the longitudinal direction of the stripe shaped opening, more preferably a direction within ± 7°, and further more pref rably within ± 2°. The longitudinal direction of the stripe shaped opening is preferably, a [0-11] direction or a crystallographically equivalent direction in the case where the

crystallographical plane of the substrate is (100), and the off-angle direction is preferably within ± 30° from a [0-11] direction or a crystallographically equivalent direction, more preferably a direction within ± 7°, and further more preferably within ± 2°. It is to be noted that in this specification, "[01-1] direction" indicates that the [01-1] direction is defined so that in general for III-V group or II-VI group semiconductor, the [11-1] surface existing between the (100) plane and the [01-1] plane becomes a plane at which the V group element or the VI group element appears.

[0020]

The semiconductor light emitting apparatus of the invention is not limited to an embodiment having the stripe shaped opening extending in the [01-1] direction. Hereinafter, other embodiments are described. Where the stripe shaped opening extends in the [011] direction or its crystallographically equivalent direction, the growth rate can be made anisotropically in association with, e.g., the growth condition, so that the rate is fast on the (100) plane whereas almost no growth is made on the (111)B plane. At that time, if the growth is made selectively on a (100) plane of the stripe shaped opening, a ridge shaped second conductive type second clad layer is formed with the (111)B plane as a side surface. In such a case, when the contact layer is subsequently formed, the contact layer is formed entirely on the ridge top made of the (100) plane as well as on the surfaces of the ridge top and the side surface made of the (111)B plane, by selecting conditions for creating more isotropic growth.

From substantially the same reason, when a wurtzite type substrate is used, as a direction that the stripe region can extend, it is preferable to use, e.g., [11-20] or [1-100] direction on (0001) plane. For HVPE (Hydride Vapor Phase Epitaxy), any direction can be used, and for MOVPE, [11-20] direction is preferable.

[0021]

When the semiconductor light emitting apparatus of the invention is designed, the thickness of the active layer and the composition of the clad layer are first determined to obtain a desired vertical divergence angle. If the vertical divergence angle is made narrower, light encroachment from the active layer to the clad layer is promoted, thereby reducing the optical density at the end facet, and improving the optical damage (COD) level at the light emission surface. Accordingly, when a high output operation is necessary, though the vertical divergence angle is set relatively narrow, there is a limitation, as for a lower side, to suppress increase of the oscillation threshold currents due to reduction of light confinement in the active layer and reduction of the temperature characteristics due to overflow of carriers. The lower limit is preferably 15° or higher, more preferably 17° or higher, and further more preferably 19° or higher. The upper limit is preferably 30° or lower, more preferably 27° or lower, and further more preferably 25° or lower. When a vertical divergence angle is d termined, structural

parameters greatly controlling a high output characteristics are a distance dp between the active layer and the protection film and a width W (hereinafter referred to as "stripe width") of the stripe shaped opening when seen in a vertical direction to the compound semiconductor layer. Generally, between the active layer and the protection film only the second conductive type first clad layer exists, and in such a situation, the distance dp is a thickness of the second conductive type first clad layer. When the active layer has a quantum well structure, the distance between the active layer closest to the protection film and the protection film becomes numeral dp. To realize lasers with achievements of high output operation and with beam closer to a circular shape in maintaining high reliability, it is necessary to set the distance dp and the width W in a proper range with good controllability.

[0022]

To realize high output operation, it is effective to widen the stripe width from a viewpoint to reduce the light density at the end facet, but to reduce the operation current, it is desirable to narrow the stripe width from a viewpoint to reduce waveguide loss. Low operation current and high output operation can be realized at the same time, and high reliability can be maintained, where the stripe width W2 around a center serving as a gaining region is made relatively narrow whereas the width around each end is made relatively broad. That is, an end width W1 at the cleavage surface preferably has an upper limit of 1000 μm or less, more preferably 500 μm or less, and a lower limit of 2 μm or greater, and more preferably 3 μm or greater. As for a center width W2, the upper limit is preferably 100 μm or less, more preferably 50 μm or less. The lower limit is typically 0.5 μm or greater, preferably 1.0 μm or greater, more preferably 1.5 μm or greater, and further more preferably 2.2 μm or greater. Differences between the end width W1 and center width W2 have an upper limit of 1000 μm or less, more preferably 500 μm or less. The lower limit is preferably, 0.2 μm or greater, more preferably 0.5 μm or greater.

[0023]

To render the transverse mode a single mode (having a light intensity profile in the transverse direction with a single peak), the stripe width cannot be made so large from viewpoints to cut off higher degree modes and to prevent hole burning from occurring, so that an upper limit of the end width W1 is preferably 5 μm or less, more preferably 4 μm or less. The center width W2 preferably has an upper limit of 6 μm or less, more preferably 5 μm or less. In regard to the differences between the end width W1 and center width W2, the upper limit is preferably 5 μm or less, more preferably 3 μm or less, and further more preferably 2 μm or less. The lower limit is preferably 0.2 μm or greater, more preferably 0.5 μm or greater.

[0024]

The lengths of the gradually increasing or decreasing portions and the portion with the

unchanged stripe width can be determined as appropriate for characteristics targeted by the semiconductor light emitting apparatus. The lengths of the gradually increasing or decreasing portions are, from a viewpoint to reduction of waveguide loss, preferably 5 to 10 μm, more preferably 10 to 50 μm. The length of the portion of the unchanged stripe width is, from a viewpoint to accuracy in cleavage, preferably 5 to 30 μm, more preferably 10 to 20 μm. The stripe shaped opening may be produced according to necessity as follows:

(1) Asymmetric openings where the stripe width and/or length of the portion with the unchanged stripe width and/or the gradually increasing or decreasing portions are not the same with respect to the respective end of the chip;

(2) Openings having no unchanged width portion but having width gradually increasing or decreasing up to the end;

(3) Openings where one end (typically, a front end facet as the light emission side for high output) is only formed with the stripe width gradually increasing or decreasing;

(4) Openings having a front end facet and a rear end facet different from each other in regard to the stripe width at the end; and

(5) Opening having a combination of some of (1) to (4).

It is effective to reduce recombination currents at each end in avoiding formation of any electrode around each end for facilitating high output operation with high reliability.

[0025]

To realize lasers with achievements of high output operation and with beam closer to a circular shape in maintaining high reliability, it is necessary to set the distance dp and the width W in a proper range with good controllability.

To realize a beam close to a circle, it is effective to narrow the stripe width, but injection current density turns into an unfavorable state from a viewpoint to suppress the bulk deterioration. Therefore, reduction of beam spot and low operation current operation can be realized at the same time, and high reliability can be maintained, where the center width W2 of the stripe shaped opening serving as a gaining region is made relatively broad whereas the end width W1 is made relatively narrow. That is, an end width W1at cleavage facet preferably has an upper limit of 10 μm or less, more preferably 5 μm or less, and further more preferably 3 μm or less, and a lower limit of 0.5 μm or greater, and more preferably 1 μm or greater. As for the center width W2, the upper limit is preferably 100 μm or less, more preferably 50 μm or less. The lower limit is preferably 1 μm or greater, more preferably 1.5 μm or greater, and further more preferably 2.2 μm or greater. Differences between the end width W1 and center width W2 have an upper limit of 100 μm or less, more preferably 50 μm or less. The lower limit is preferably, 0.2 μm or greater, more preferably 0.5 μm or greater.

[0026]

To render the transverse mode a single mode (having a light intensity profile in the transverse direction with a single peak), the stripe width cannot be made so large from viewpoints to cut off higher degree modes and to prevent hole burning from occurring, so that an upper limit of the end width W1 is preferably 5 μm or less, more preferably 4 μm or less. The center width W2 preferably has an upper limit of 6 μm or less, more preferably 5 μm or less. In regard to the differences between the end width W1 and center width W2, the upper limit is preferably 5 μm or less, more preferably 3 μm or less, and further more preferably 2 μm or less. The lower limit is preferably 0.2 μm or greater, more preferably 0.5 μm or greater.

[0027]

The lengths of the gradually increasing or decreasing portions and the end portion can be designed as appropriate for characteristics targeted by the semiconductor light emitting apparatus. The length of the gradually decreasing portion is, from a viewpoint to reduction of waveguide loss, preferably 5 to 10 μm, more preferably 10 to 50 μm. The length of the end portion is, from a viewpoint to accuracy in cleavage, preferably 5 to 30 μm, more preferably 10 to 20 μm. The stripe shaped opening may be produced according to necessity as follows:

(1) Asymmetric openings where the stripe widths or lengths of the portion of the end, the gradually increasing or decreasing portions are not the same with respect to the respective ends of the chip;

(2) Openings having no unchanged width portion but having width gradually increasing or decreasing up to the end;

(3) Openings where one end (typically, a front end facet) is only formed with the stripe width gradually increasing or decreasing;

(4) Openings having a front end facet and a rear end facet different from each other in regard to the stripe width at the end; and

(5) Opening having a combination of some of (1) to (4).

It is effective to suppress bulk deterioration due to current injection to the stripe shaped opening around the end and to reduce recombination currents at each end in avoiding formation of any electrode around each end form a view point to production of a laser having a small beam spot with high reliability.

[0028]

In general, when a stripe width in the semiconductor layer is determined by etching (particularly, wet etching), if the stripe width is made gradually increasing or decreasing, the edge of the stripe changes stepwise due to fuzziness on the stripe edge because some specific plane selectively comes out readily, this stepwise undulation at the edge readily causes disorders such as ripples in the far field pattern in the horizontal direction, a large side peak, and the like. On the other hand, with a desirable embodiment of the invention, because the stripe width

gradually increasing or decreasing portions are formed by etching of SiNx amorphous film, the stripe width can be increased or decreased linearly, so that an isolated single peak can be formed easily without ripple or side peak.

With respect to the distance dp, an upper limit is preferably 0.60 μm or less, more preferably 0.50 μm or less, further more preferably 0.45 μm or less, and still further more preferably 0.40 μm or less. A lower limit is preferably 0.10 μm or greater, more preferably 0.15 μm or greater, and further more preferably 0.20 μm or greater. However, the above optimum range may be shifted depending on the use object (such as settings of divergence angle, etc.) and materials (such as refractive index, resistance, etc.). With respect to the optimum range, it should be noticed that the above structural parameters may affect each other.

[0029]

For the ridge type compound semiconductor layer, a lower In content of the compound crystal composition is preferred because changes to the lattice constant or refractive index become less. For example, where the In content in the semiconductor layer may vary at 10 % or more, if the In content in the ridge type compound semiconductor layer is 10 %, the In content shift amount becomes 1 % or higher. Generally, in a III-V group semiconductor containing In, if the In content is deviated 1 % from the lattice matching condition, the critical film thickness becomes about 1 μm, so that high density transfer may occur during the ridge production, and so that there may raise a problem that the device property and reliability may be impaired. To avoid such a problem, some restriction may be imposed such that the growth condition, the protection film shape, and the like are strictly controlled so that the In content becomes less than about 10 % as a proportion. On the other hand, if the In content is small, the In content shift amount can be suppressed to be less than 1 % even where the In content in the semiconductor layer is greatly changed. Therefore, the In content of the compound crystal of the ridge type compound semiconductor layer is preferably 10 % or less, more preferably 5 % or less, and further more preferably 1 % or less.

It is to be noted that if the second conductive type second clad layer is structured of a III-V group compound semiconductor containing Al such as Al(Ga)As, Al(Ga)AsP, Al(GaIn)As, Al(GaIn)P, Al(GaIn)N, and the like, surface oxidation can be preferably prevented by covering the substantially entire surface on which a crystal may be grown with a III-V group compound semiconductor containing no Al such as GaAs, GaAsP, GaInAs, GaInP, GaInN, and the like.

[0030]

When the semiconductor light emitting apparatus according to the invention is manufactured, after a double hetero structure is formed on a substrate, a ridge type second conductive type second clad layer and a second conductiv type contact layer are selectively grown using a protection film, and it is preferable to form electrodes on the ridge top and the

side surfaces without forming a protection film on the ridge top and the side surfaces. The specific conditions for growing the respective layer may vary depending on the layer's composition, growing method, shape of the apparatus, etc., and in a case that a compound semiconductor of group III-V is grown by the MOCVD method, preferably, the double hetero-structure is formed at a growing temperature of about 650 to 750 °C with a V/III ratio of about 20 to 60 (in the case of AlGaAs) or about 350 to 550 (in the case of AlGaInP), whereas the ridge portion is formed at a growing temperature of 600 to 700 °C with V/III ratio of about 40 to 60 (in the case of AlGaAs) or about 350 to 550 (in the case of AlGaInP). Where the ridge portion selectively grown in use of the protection film contains, particularly, Al such as in AlGaAs and AlGaInP, it is very preferable if a very small amount of an HCl gas is introduced during the growth, because the gas prevents polycrystals from depositing. However, as the Al is contained much more in the composition, or as the ratio of the mask portion to the opening is higher, a necessary introduction amount of HCl increases for making a selective growth only on the opening (selective mode) in preventing polycrystals from depositing where other growing conditions are unchanged. On the other hand, if the HCl gas is introduced too much, the AlGaAs layer may not be grown, and conversely, although the semiconductor layer is etched (etching mode), a necessary introduction amount of HCl increases for entering to the etching mode as the Al is contained much more in the composition, even where other growing conditions are unchanged. The optimum introduction amount of HCl greatly depends on a molecular number of the group III source supply including Al such as trimethylaluminum or the like. More specifically, the ratio of the supply molecular number of HCl to group III source supply molecular number including Al (HCl / Group III) is preferably 0.01 or more, more preferably 0.05 or more, and further more preferably 0.1 or more. An upper limit is preferably 50 or less, more preferably 10 or less, and further more preferably 5 or less. It is to be noted that ridge component control tends to be difficult when a compound semiconductor layer containing In at the ridge is selectively grown (particularly, HCl introduction).

[0031]

The semiconductor light emitting apparatus according to the invention includes, on a substrate, at least a compound semiconductor layer containing an active layer, a protection film having an opening formed on the layer, a ridge type compound semiconductor layer having a smaller refractive index than that of the active layer on the opening, and a contact layer formed on substantially the entire surface of the ridge shape, and the semiconductor light emitting apparatus can realize a high output operation where the width of the opening is set from 2.2 μm to 1,000 μm, and the resistance of the entire apparatus can be reduced to a low value by creating an adequate contact area between the contact layer and the electrodes adjacent to the contact layer and the second conductive type second clad layer. A portion of the ridge top and side

surfaces on which the contact layer is formed can be covered with a protection film for the purpose of preventing the layer from oxidizing or the like. In this embodiment, the apparatus can have a lower resistance in comparison with an apparatus formed with a protection film without forming any contact layer on the ridge side surface, and falls within the scope of the invention. It is particularly effective to reduce the resistance of the entire apparatus where a material having a high specific resistance such as AlGaInP based and AlGaInN based (especially, of p-type).

[0032]

In this invention, a portion of the ridge type compound semiconductor layer having a smaller refractive index than that of the active layer formed on the opening is formed as to overlap the protection film. The overlapped portion of the second conductive type second clad layer over the insulation film is 0.01 μm as a lower limit, more preferably 0.1 μm or greater, and as an upper limit, preferably less than 2.0 μm (excepting 2.0 μm), and more preferably 1.0 μm or less. Such an embodiment improves the controllability of the light profile encroaching around boundaries between the protection film and the ridge bottom, thereby reducing optical absorption at the contact layer formed on the ridge top and the side surfaces. In this case, a protection film formed on the side surfaces of the ridge portion is not always necessary unlike the conventional ridge waveguide type laser, so that such use is advantageous for simplification of the processes and cost reduction.

In this invention, the width of the opening is preferably set in a size of 4 μm or less, and this feature allows the transverse mode to be a single mode (light intensity profile in the transverse direction having a single peak). The semiconductor light emitting apparatus of the invention can form the far field pattern to be a single peak, so that the apparatus can be used to provide a desirable laser for broad applications such as information processing and optical telecommunication.

Where a clad layer is formed between the active layer and the protection film, and where the thickness of the clad layer is set to 0.10 μm or greater or 0.50 μm or less, a high output operation can be realized easily with the stripe width.

[0033]

Furthermore, where the protection film is made of a dielectric such as SiN_x film, SiO_2 film, SiON film, Al_2O_3 film, ZnO film, SiC film, and the like, the apparatus can readily realize a high output operation under the above condition. At that time, it is preferable to set the refractive index difference between the protection film and the second conductive type first clad layer at the oscillation wavelength equal to or higher than 0.5 and equal to or less than 2.0.

The height (thickness) of the second conductive type second clad layer is preferably set to about 0.25 to 2.0 times of the width W of the protection film opening as described above.

If within this range, it is preferable because the second conductive type second clad layer would not be projected so much in comparison with the surroundings (the current block layer or ridge dummy layer as described below), because the device life would not be affected due to stresses exerted to the ridge portion when the device is used in a manner of the junction down, and because post processes such as a forming process for electrodes are done easily since it is very low in comparison with its vicinity.

In addition to the structure of the invention, a clad in the ridge shape is formed by re-growth where an antioxidant layer is formed on a side of epitaxial surface of the double hetero structure, thereby easily preventing a high resistance layer, which may increase a passage resistance at re-growth boundaries from occurring.

[0034]

As the antioxidant layer, there is no special limitation on selection of the material as far as it is hardly oxidized or it is cleaned up easily. More specifically, a compound semiconductor layer of III-V group having a low containing rate of readily oxidized elements such as Al (about 0.3 or less) is exemplified. It is preferable that the antioxidant layer does not absorb light from the active layer by selecting the material or thickness of the antioxidant layer to avoid the operation current from increasing. The material of the antioxidant layer can be ordinarily selected from materials having a wider band gap than that of the active layer material, but a material, even where its band gap is narrow, can be used where the thickness is 50 nm or less, preferably, 30 nm or less, more preferably, 10 nm or less because light absorbing can be substantially neglected.

With the embodiment, the profile controllability of light otherwise encroaching adjacent regions between the protection film and the ridge is made better where the clad layer of the re-growth portion is grown as to be over the top of the protection film; the side surface of the clad layer is prevented from oxidizing by growing the contact layer on substantially the whole surface on which a crystal can be grown on the re-grown clad layer; the contact resistance to the electrode may be reduced by increasing the contact area in contact with the electrode on a side of the epitaxial surface. Growing the re-growing clad layer and the contact layer coming over the protection film can be done independently or done in combination. Where the ridge is formed by re-growth, a ridge dummy layer may be formed which has a larger area than the ridge portion subjecting to current injection and in which no current injection is made in order to improve the composition of the ridge portion and the controllability of the carrier concentration and growth rate. In this situation, an insulation covering layer such as an oxide layer or a thyristor structure is formed at a portion of the ridge dummy layer to prevent the current from passing. Where the current injection stripes are formed on the off-angled substrate in a perpendicular direction as much as possible to the off direction, although th ridge of th

re-growth becomes transversely asymmetric, the light profile that comes out the vicinity of the protection film and the ridge has a good symmetry, because the refractive index difference between the protection film and the clad layer of the ridge portion is easily made larger than the conventional block layer made of a semiconductor layer as shown in Fig. 5, and because the clad layer of the re-growth portion can be grown as to cover the top surface of the protection film by selecting the stripe direction properly, and therefore, this apparatus can obtain a fundamental transverse mode oscillation which is stable even at a high output stage. Thus, this invention is applicable to various ridge stripe type waveguide structure semiconductor light emitting apparatuses.

[0035]

In accordance with a desirable embodiment of the invention, the refractive index of the second conductive type first clad layer is larger than the refractive index of the second conductive type second clad layer. Therefore, this can suppress expansion of the light profile (near field pattern) to the ridge portion, thereby achieving improvements in symmetry of the vertical divergence angle (far field pattern), suppression of side peaks of horizontal divergence angle (far field pattern), and improvements in laser property by suppressed light absorption at the contact layer and in the reliability.

With another desirable embodiment of the invention, the antioxidant layer is formed at least right below the protection film opening on the second conductive type first clad layer, or namely, at the stripe shaped opening and, preferably, on the opposite sides of the stripe shaped opening. This may prevent a high resistance layer that may increase the passing resistance from occurring on the re-growth boundary where the clad layer of the ridge portion is formed by re-growth. If impurities such as oxygen exist in a large amount at the re-growth boundary, light absorption (heating) at the boundary due to lowered crystal quality and promotion of impurity diffusions through lattice defects may be induced, thereby inviting impairments on property and reliability.

[0036]

This invention is applicable to various ridge waveguide type semiconductor light emitting apparatuses, and the apparatus according to the invention can be combined with various embodiments as exemplified below.

(1) An apparatus formed with a current block layer such as a semiconductor or dielectric on the outer side of the protection film constituting the opposite sides of the stripe shaped opening to improve cleavage and yield during assembling and rendering the life time longer by reducing stresses in the ridge portion when the apparatus is assembled with a junction down state.

(2) An apparatus capable of self-excited oscillating by setting the width of the stripe

shaped opening and the distance between the active layer and the protection film in a proper range and by forming the vertical divergence angle of the light in a specific range.

(3) An apparatus formed with a structure having a ridge dummy region on an outer side of the protection film constituting the opposite sides of the stripe shaped opening to readily control the thickness of the stripe shaped opening, the composition, and the carrier concentration.

[0037]

As a semiconductor laser apparatus to which this invention applies, the light source for information processing (typically, AlGaAs based (wavelength about 780 nm), AlGaInP based (wavelength 600 nm band), InGaN based (wavelength about 400 nm) are described, but this invention is also applicable to broad use (particularly, high output operation) such as a semiconductor laser apparatus for telecommunication, other than the above, e.g., a signal light source laser for telecommunication (typically, having an active layer made of InGaAsP or InGaAs, 1.3 μm band, 1.5 μm band), a light source laser for fiber excitation (about 980 nm using an InGaAs strained quantum well active layer / GaAs substrate, about 1480 nm using an InGaAsP strained quantum well active layer / InP substrate). The laser having a spot close to a circle, even for telecommunication, is advantageous to the extent of raising the coupling efficiency with fibers.

In addition, the structure of this invention is applicable to a light emitting diode (LED) such as of end facet emitting type other than semiconductor lasers.

[0038]

[Embodiments]

Hereinafter, examples and comparative examples are described to illustrate the invention in detail. The material, concentration, thickness, manipulation order, and the like indicated in the following examples are properly changeable as far as not goes beyond the spirit of the invention. Accordingly, the scope of the invention is not limited to the detailed examples shown in the following examples.

[0039]

[Example 1]

In this example, a semiconductor light emitting apparatus according to the invention having a cross-sectional structure shown in Fig. 1 was manufactured.

On a GaAs substrate 101 having a thickness of 350 μm and an off-angle of about 10° to 15° in a [0-1-1]A direction from (100) plane, first, a Si doped n-type GaAs buffer layer ($n = 1 \times 10^{18}$ cm^{-3}), which is not shown in Fig.2, having a thickness of 0.5 μm, an n-type first clad layer 102 made of a Si doped $Al_{0.75}Ga_{0.25}As$ ($n = 1 \times 10^{18}$ cm^{-3}) having a thickness of 1.5 μm, an n-type second clad layer 103 made of a Si doped $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ ($n = 1 \times 10^{18}$ cm^{-3}) having a

thickness of 0.2 μm, a triple quantum well (TQW) active layer 107 made of (three layers) an undoped $Ga_{0.44}In_{0.56}P$ well layer 105 having a thickness of 5 to 6 nm sandwiched by an optical guide layers 104 made of an undoped $(Al_{0.5}Ga_{0.5})_{0.5}In_{0.5}P$ having a thickness of 50 nm or a barrier layers 106 made of an undoped $(Al_{0.5}Ga_{0.5})_{0.5}In_{0.5}P$ having a thickness of 5 nm, a p-type first clad layer 108 made of a Zn doped $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ ($p = 7 \times 10^{17}$ cm^{-3}) having a thickness of 0.25 μm, a Zn doped p-type $Ga_{0.5}In_{0.5}P$ antioxidant layer 109 ($p = 1 \times 10^{18}$ cm^{-3}) having a thickness of 5 nm were accumulated orderly by an MOCVD method to form a double hetero-structure (Fig. 1(a)). At that time, the antioxidant layer preferably has a selected composition so as not to absorb light generated by re-combinations in the active layer in order to reduce the threshold current, but can be used as an over-saturation absorbing layer upon absorbing light intentionally to do self-pulsation. It is further effective to change the composition of the $Ga_xIn_{1-x}P$ antioxidant layer with Ga rich side (X = 0.5 to 1) or to add Al in a small amount ($(Al_xGa_{1-x})_{0.5}In_{0.5}P$, X = approximately 0.1 to 0.2) to prevent the light from being absorbed.

Subsequently, a SiN_x protection film 110 as an insulator (having a refractive index 1.9 and wavelength 650 nm) was deposited by 200 nm on the surface of the double hetero substrate. Many stripe shaped openings 107 were opened in the SiN_x film 110 by a photolithographic method in a [01-1] B direction, which is perpendicular to the off-angle direction. In a general III-V group compound semiconductor, a [01-1]B direction is defined so that the (11-1) plane located between the (100) plane and the (01-1) plane is a plane where the V group element appears.

A ridge made of a Zn doped p-type $Al_{0.75}Ga_{0.25}As$ clad layer 112 ($p = 1.5 \times 10^{18}$ cm^{-3}, refractive index 3.3, wavelength 655 nm) having a thickness or height of 2.0 μm at the ridge center and a Zn doped GaAs contact layer 113 having a thickness of 0.5μm, was formed on the stripe shaped opening 111 by selective growth using an MOCVD method (Fig. 1(b)). At that time most of the side surfaces of the ridge was (311) A plane or other planes close to the plane, and the clad layer of the re-growth portion was grown as to cover the top surface of the protection film serving as an insulator, thereby allowing the contact layer to grow on substantially the entire surface on which a crystal can grow on the clad layer of the re-growth portion. Therefore, the device can make better the controllability of the light profile which comes out the vicinity of the protection film and the ridge, can suppress the side surface of the clad layer from oxidizing, and can reduce the contact resistance with the electrode by increasing the contact area in contact with the electrode on the epitaxial surface side. This tendency is remarkable where the re-growth ridge is AlGaAs, particularly where the Al content of the AlAs compound crystal is set 0.2 to 0.9, preferably 0.3 to 0.8..

[0041]

With the above MOCVD method, trimethyl gallium (TMG), trimethyl aluminum (TMA), and trimethyl indium (TMI) were used for raw materials for III group source, and arsine and phosphine were used for raw materials for V group, and hydrogen was used for carrier gas. Dimethyl zinc was used for the p-type dopant, and disilane was used for the n-type dopant. Moreover, when the ridge was grown, the HCl gas was introduced at a molecular ratio of HCl / group III of 0.2, particularly, 0.3 as a molecular ratio of HCl / TMA.

From SEM observation, the ridge shaped p-type second clad layer (second conductivity type second clad layer) made of the Zn doped $Al_xGa_{1-x}As(x=0.75)$ was confirmed as formed in about 0.4 μm in covering the protection film made of SiNx as shown in Fig. 1. The p-GaAs contact layer covered the whole surface of the ridge side wall at every stripe width. This could prevent the ridge shaped p-type second clad layer made of the Zn doped $Al_xGa_{1-x}As(x=0.75)$ from being exposed on a surface and oxidized at the surface. There would be no problem to cover a part or the whole surface of the ridge side wall with a SiNx protection film likewise in a conventional method, but in this example, no protection film made of dielectric or the like was formed on the ridge side surface in consideration of simplification of processing, reduction of contact resistance, etc. The ridge shape became slightly asymmetric horizontally due to influence of the off-angle of the substrate, though not shown.

[0042]

Subsequently, a p-type electrode 110 was deposited. After the substrate was made thinner to 100 μm, an n-type electrode 111 was deposited on the substrate and was alloyed (Fig. 1(c)). A laser resonator structure was formed by cutting into chip bars by cleavage from the wafer thus produced. The length of the resonator was set to 500 μm at that time. After an asymmetric coating of 10 % on the front end side and 90 % on the rear end side was made, the bar was separated into each chip by secondary cleavage.

After assembled in a manner of the junction down, characteristics of current vs. optical output, current vs. voltage were measured under continuous wave (CW) at 25 °C. Very good characteristics of current vs. optical output, current vs. voltage were shown, and the threshold value was 1.7 V, a low value corresponding to a bandgap of the active layer, as a confirmation of non-existence of any high resistance layer. A series resistance was small, 5 to 6 Ω, and it was confirmed that the contact resistance between the p-type contact layer and the p-type electrode was very small. The laser of this example could obtain a high output up to optical output 120 mW operation, have very good property such that the oscillation wavelength was 655 nm in average; the threshold current was 20 mA in average; the slope effectiveness was 1.0 mW/mA in average. The laser had a vertical divergence angle of 23° in average during the optical output of 50 mW and obtained the single peak far field pattern (beam divergence angle) as exactly designed, and it was confirmed that the optical profil can be controlled very well.

From this result, it is assumed that no adverse effect comes out to kink levels or the like due to slight asymmetry of the re-grown ridge shape, since the transverse mode is basically controlled by the SiNx protection film. It is to be noted that in this specification, "a single peak" does not necessarily mean that it allows a sole peak but means that no other peak having an intensity one tenth of the maximum peak intensity exists. According to those results, the laser structure of the invention is useful for light source for writing to optical discs such as DVD, etc. In addition, it was turned out that the structure had high reliability (stable operation for 1000 hours or more under high output of 100 mW, high temperature of 60°C). Moreover, in this example, it was confirmed that the respective devices of each batch or between the batches had less deviation in device property.

[0043]

Where the stripe width was made broader than the above example, it was turned out that the almost all devices did not oscillate with a single transverse mode (single peak in light intensity profile in the transverse direction) when the stripe width at the center reached 5 μm or grater. This indicates that it is desirable to set the stripe width to be 5 μm or less to realize the single transverse mode oscillation.

As a result upon confirmation through a simulation of a region operable for high output based on the experimental results, it was turned out that the effective refractive index gap in the transverse direction in the active layer should be set around 5×10^{-3} to 1.3×10^{-2}.

[0044]

In this embodiment, n-side clad layer is a two layer structure made of the Si doped $Al_{0.75}Ga_{0.25}As$ clad layer ($n=1 \times 10^{18}$ cm^{-3}) 102 having a thickness 1.5 micron meters and the Si doped n-type $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ clad layer ($n=1 \times 10^{18}$ cm^{-3}) 103 having a thickness 0.25 micron meter, but one layer structure made of either composition can be used (provided that the thickness is about the same as the thickness of two layers). To render perfectly lattice matching to the GaAs substrate, an AlGaAsP layer may be formed in adding P in a small amount in the AlGaAs layer, and for example, the Zn doped p-type $Al_{0.75}Ga_{0.25}As$ clad layer ($p=1.5 \times 10^{18}cm^{-3}$) 112 can be an $Al_{0.75}Ga_{0.25}As_{0.97}P_{0.03}$.

[0045]

[Example 2]

As shown in Fig. 2(a), a chip was produced in the same manner as in Example 1 except that a patterning was so made that the center width (W2) of the stripe shaped opening was constant, 4μm, and the stripe width was gradually reduced at around the end, and the end width (W1) at the cleavage facet is constant, 5μm. This fabrication improved the maximum optical output up to 150 mW and enabled to stably operate th apparatus for no l ss than 1000 hours at 60 Celsius degrees, 50 mW, and this turned out that the apparatus can have a higher reliability at

a high output than the conventional apparatus (35mW). From this result, the laser structure of the invention can be used as a light source for writing (faster writing than the prior art) on optical discs such as DVD, and the like.

[0046]

[Example 3]

A chip was manufactured according to substantially the same steps as in Example 1 except that: a quadruple quantum well (QQW) active layer including an undoped $(Al_{0.5}Ga_{0.5})_{0.5}In_{0.5}P$ guide layer having a thickness of 70 nm and four well layers made of an undoped $Ga_{0.44}In_{0.56}P$, and a Zn doped p-type($Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ clad layer ($p = 1 \times 10^{17}$ cm^{-3}) having a thickness of 0.35 μm was formed; the stripe shaped opening was subject to patterning so that the width of the stripe shaped opening became 2.5 μm, constant, at a center (W2), gradually decreasing towards each end (W1), and 1.5 μm, constant, at cleavage facet, as shown in Fig. 2(b); at that time, the length at the center portion was 200 μm; the ridge top of the Zn doped p-type $Al_{0.75}Ga_{0.25}As$ ($p = 1.5 \times 10^{18}$ cm^{-3}; refractive index 3.3, wavelength 655 nm) was 1.5 μm in height; the length of the resonator was 350 μm; an asymmetric coating of 32 % on the front end and 80% on the rear end was made.

[0047]

The laser of this example could achieve self-excited oscillation up to operation of an optical output of 5 mW or greater even at a high temperature (70 Celsius degrees), and had very good property such that the oscillation wavelength was 655 nm in average; the threshold current was 25 mA in average; the slope effectiveness was 0.5 mW/mA in average. The laser had a vertical divergence angle of 30° in average and obtained the single peak far field pattern (beam divergence angle) as exactly designed, and it was confirmed that the optical profile can be controlled very well. The horizontal divergence angle was 15° in average and was about a half of the vertical divergence angle, which came closer to a circle more than a conventional high output laser. With respect to the far field pattern in the horizontal direction, a good single peak with no ripple or side peak was obtained. This may suggest that factors are not only that the stripe width is decreased straight but also that the laser was little affected from the ridge undulation of the gradually decreasing portion of the stripe width because the ridge portion was grown laterally. It is to be noted that in this specification, "a single peak" does not necessarily mean that it allows a sole peak but means that no other peak having an intensity one tenth of the maximum peak intensity exists. According to those results, the laser structure of the invention is useful for light source for reading for optical discs such as CD, MD, etc. In addition, it was turned out that the structure had high reliability (stable operation for 1000 hours or more under output of 8 mW, high temperature of 70°C). Moreover, in this example, it was confirmed that the respective devices of each batch or between the batches had less deviation in device

property.

[0048]

Where the center width (W2) of the stripe shaped opening was made broader than the above example, it was turned out that the almost all devices did not oscillate by self-excitation when the width reached 3 μm or grater. This indicates that it is desirable to set the center width (W2)of the stripe shaped opening to be less than 3 μm to realize the self-excited oscillation.

As a result upon confirmation through a simulation of a region in which the center width (W2) of the stripe shaped opening and the thickness dp of the second conductive type first clad layer satisfy the self-excited oscillation condition, it was turned out that the effective refractive index gap in the transverse direction in the active layer should be set around 2×10^{-3} to 7×10^{-3} and that light encroaching rate T_{ACTOUT} to the respective ridge sides should be set to around 10 to 40 %.

[0049]

[Comparative Example 1]

A laser chip was manufactured with the same conditions as in Example 1 except that a ridge made of the Zn doped p-type($Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ clad layer ($p = 7 \times 10^{17}$ cm^{-3}; refractive index 3.3, wavelength 655 nm) and Zn doped GaAs contact layer having a thickness of 0.5μm is formed at the opening 111 in a stripe shape by selective growing in use of the MOCVD method.

After assembled in a manner of the junction-down, the laser had a high passage resistance of about 10 ohm and an optical output up to merely around 70 mW, where characteristics of current vs. optical output were measured under continuous wave (CW) at 25 °C. Thus, during the reliability test done under high output of 35 mW, high temperature of 60°C in the same way as in Example 1, the tested twenty devices all increased suddenly the operation current between several tens hours and several hundreds hours after the start of continuous wave operation and fallen to a phenomenon that no optical output came out. The grounds for increase of the passage resistance, reduction of the maximum optical output, inferior reliability at high temperature, high output operation were presumably, because of slight shifts in designed amounts of the composition of the ridge portion clad layer made of the p-type $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$, that the near field pattern (beam divergence angle) is made unstable due to deviations in the refractive index, that dislocations occurred due to lattice mismatching, and further that the p-type $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ clad layer is subject to higher resistivity and heat resistance in comparison with the p-type $Al_{0.75}Ga_{0.25}As$ layer of Example 1.

[0050]

[Comparative Example 1]

A laser chip was manufactured with the same conditions as in Example 3 except that a

ridge made of the Zn doped p-type($Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ clad layer ($p = 7 \times 10^{17}$ cm^{-3}; refractive index 3.3, wavelength 655 nm) and Zn doped GaAs contact layer having a thickness of 0.5µm is formed at the opening 111 in a stripe shape by selective growing in use of the MOCVD method.

After assembled in a manner of the junction-down, the threshold current increased up to 30mA in average and the laser could not achieve self-excited oscillating at a high temperature (70°C), where characteristics of current vs. optical output were measured under continuous wave (CW) at 25 °C. Thus, during the reliability test done under 5 mW, 70°C in the same way as in Example 1, the tested twenty devices all increased suddenly the operation current between several tens hours and several hundreds hours after the start of continuous wave operation and fallen to a phenomenon that no optical output came out. The grounds for stoppage of the self-excited oscillating at the high temperature (70°C) and inferior reliability at high temperature operation, in comparison with Example 1 which tends to increase the operation current at a high temperature, were presumably, because of slight shifts in designed amounts of the composition of the ridge portion clad layer made of the p-type $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$, that the near field pattern (beam divergence angle) is made unstable due to deviations in the refractive index, that dislocations occurred due to lattice mismatching, and further that the p-type $(Al_{0.7}Ga_{0.3})_{0.5}In_{0.5}P$ clad layer is subject to higher resistivity and heat resistance in comparison with the p-type $Al_{0.75}Ga_{0.25}As$ layer of Example 1 to change the current divergence profile.

[0051]

[Advantages of the Invention]

In accordance with the invention, upon designing a semiconductor light emitting apparatus such as a ridge waveguide stripe laser, at least having on a substrate, a compound semiconductor layer containing an active layer, a protection film having an opening formed on the compound semiconductor layer, a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the opening, and an electrode formed on the ridge type compound semiconductor layer, to have a layer whose In compound crystal composition is no less than 5%, and to render the ridge type compound semiconductor layer include an In compound crystal composition of no more than 10%, the apparatus can improve the controllability of the ridge (mesa) shape and the compound crystal composition (lattice constant, refractive index, etc.) of the semiconductor layer constituting the ridge and also render the laser property stable as well as improve reliability of the laser operation.

[0052]

According to the invention, where a structure is formed with no protection film made of an insulator on the ridge side surface in forming a ridge type compound semiconductor layer at the stripe region to which current is injected by selective growth in use of a protection film

made of an insulator, not only the stripe width can be reduced linearly, but also the gradually reduced portion in the stripe width is little affected from undulations of the ridge portion because the ridge portion grows in the lateral direction, thereby easily bringing a good single isolated peak without any ripple or side peak in the far field pattern in the horizontal direction.

Moreover, according to the invention, by forming a contact layer as to cover substantially the whole surface including the ridge top and side surfaces formed by growth to increase the contact area between the contact layer and the electrode, the contact resistance can be reduced, and laser property and reliability can be improved upon prevention of surface oxidation of the ridge side surface of the clad layer (containing, particularly, Al).

Furthermore, the semiconductor light emitting apparatus also has an advantage to greatly improve the production yield because manufactured with simplified processes not using complicated and very fine photolithography as used conventionally.

With this invention, a high output operation can be realized while a lower operation current is kept in rendering wider the stripe width at the end in comparison with the center. In a meantime, a semiconductor light emitting apparatus such as a ridge waveguide stripe laser can make a laser having beam close to a circle in keeping high reliability because the width of the protection film opening is made narrower at around the apparatus end than at the apparatus center. Therefore, optical loss in an optical system can be reduced, and the laser property when assembled as an optical pickup and the assembling yield became very good since the optical axis adjustment in the horizontal direction is easily made.

Moreover, even when a substrate having a large off-angle with respect to some lower degree plane direction such as (100) is used for rendering the wavelength shorter likewise the AlGaInP/GaInP based visible laser, the horizontally asymmetric property of the ridge shape of the ridge waveguide type laser is little affected from the horizontally asymmetric property of the optical intensity profile, so that a stable basic transverse mode can be obtained up to a high output operation.

[Brief Description of the Drawings]

[Fig. 1] It is a cross section illustrating a manufacturing process of a semiconductor light emitting apparatus of a first example.

[Fig. 2] It is a plan view illustrating width changes of a stripe-shaped opening at a resonator direction in a semiconductor light emitting apparatus of second and third examples.

[Fig. 3] It is a cross section illustrating a conventional semiconductor light emitting apparatus and its manufacturing method where a ridge portion is formed by re-growth in forming a protection film at a non-ridge portion and where a contact layer is formed only on the ridge top.

[Fig. 4] It is a cross section illustrating a manufacturing process of a conv ntional semiconductor light emitting apparatus and its manufacturing method whose ridge portion is

formed by etching.

[Fig. 5] It is a cross section illustrating a semiconductor light emitting apparatus having an inner-stripe structure of a ridge type or groove type using a current block layer made of a semiconductor and its manufacturing method.

[Fig. 6] It is a cross section illustrating a conventional (AlGa)InP based red ray visible laser manufactured on a GaAs substrate.

[Description of Reference Numbers]

101 substrate

102 first conductivity type first clad layer

103 first conductivity type second clad layer

104 optical guide layer

105 barrier layer

106 well layer

107 MQW active layer

108 second conductivity type first clad layer

109 antioxidant layer

110 protection film

111 stripe shaped opening

112 second conductivity type second clad layer

113 contact layer

114 epitaxial side electrode

115 substrate side electrode

W1 end width

W2 center width

301 substrate

302 first conductivity type clad layer

303 active layer

304 second conductivity type first clad layer

305 antioxidant layer

306 protection film

307 stripe shaped opening

308 second conductivity type second clad layer

309 contact layer

310 epitaxial side electrode

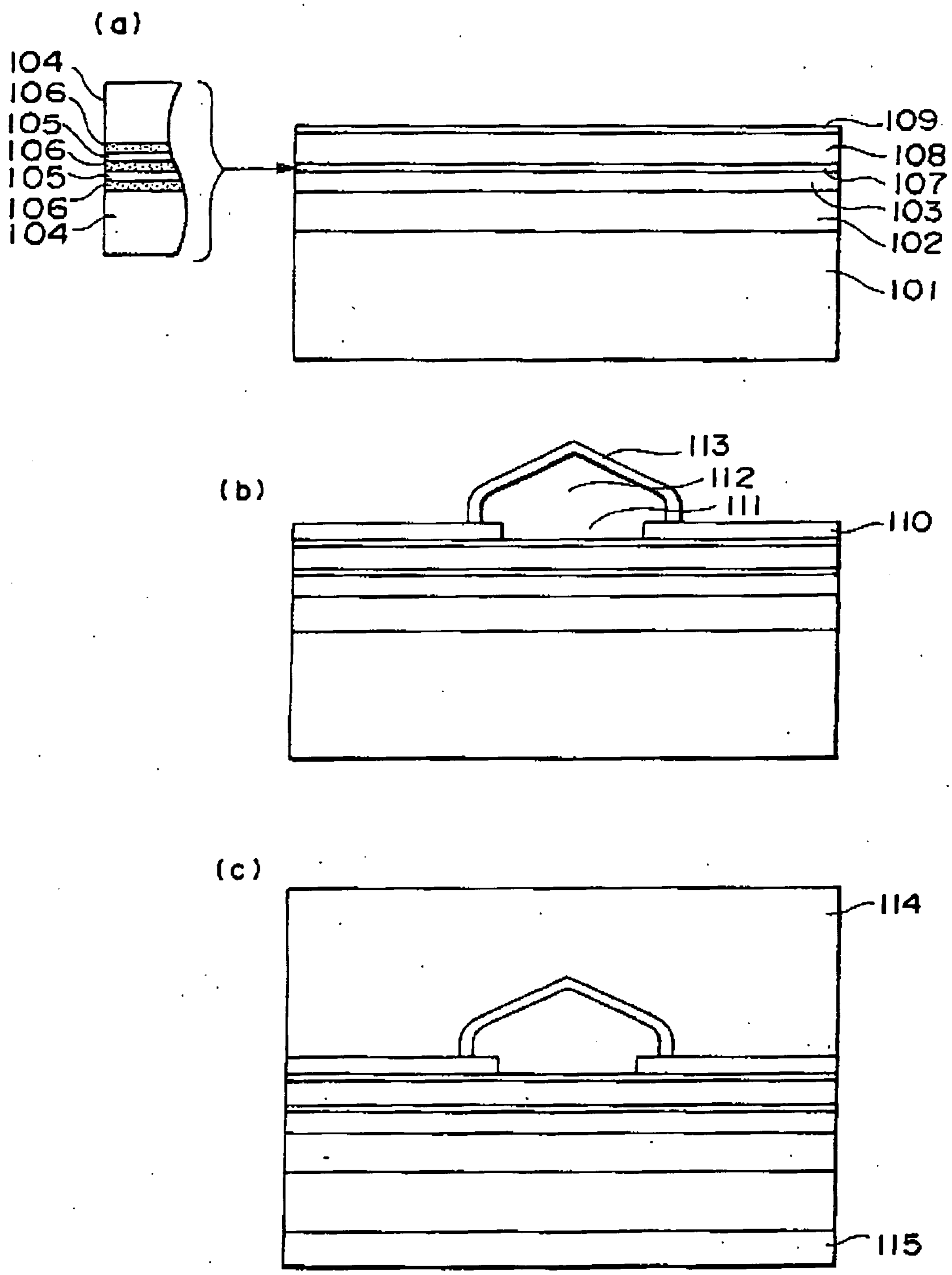
311 substrate side lectrode

401 substrate

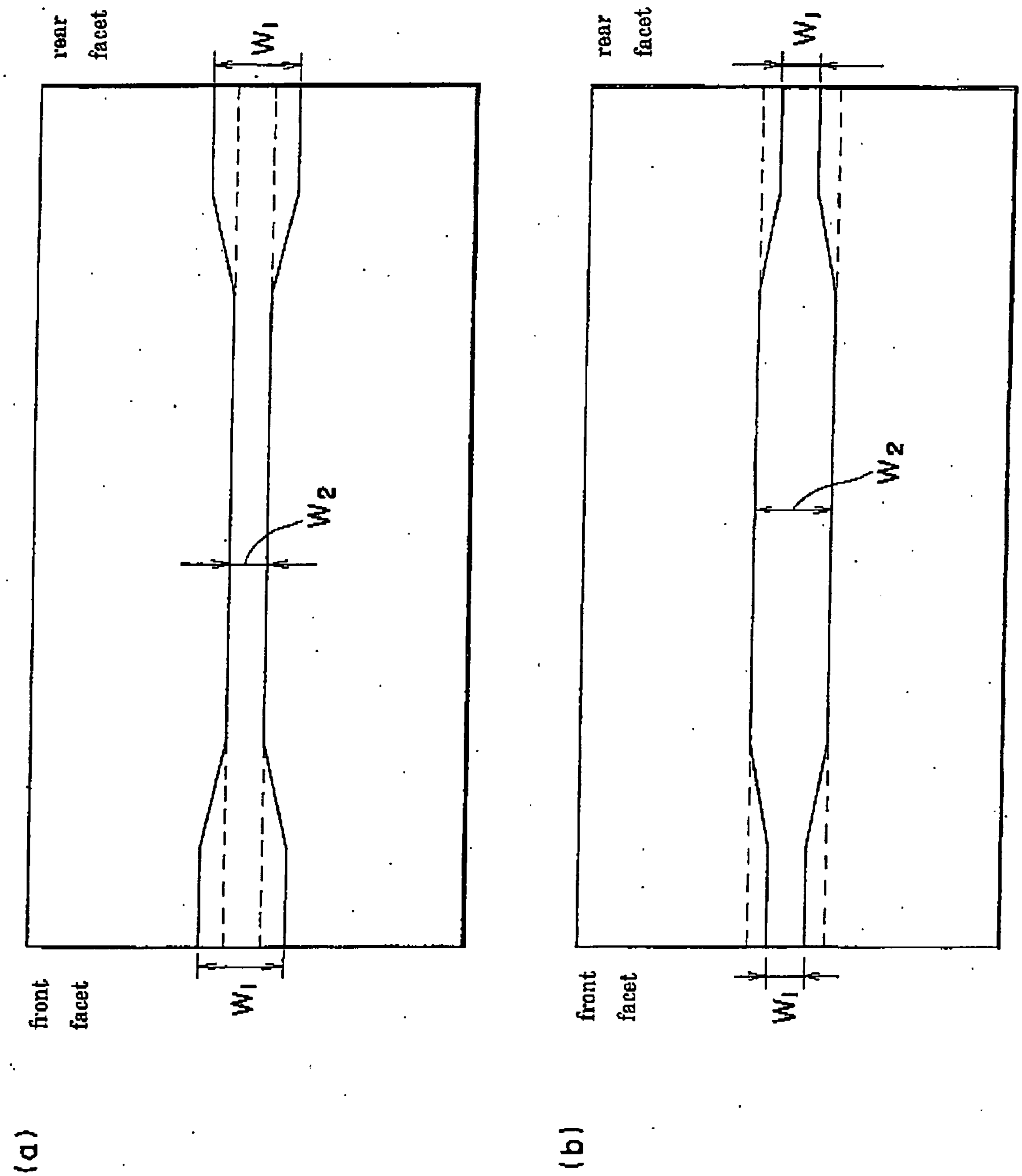
402 first conductivity type clad layer
403 active layer
404 second conductivity type clad layer
405 contact layer
406 protection film
407 epitaxial side electrode
408 substrate side electrode
409 ridge portion
410 non-ridge portion
411 resist
501 substrate
502 first conductivity type clad layer
503 active layer
504 first conductivity type first clad layer
505 first conductivity type current block layer
506 second conductivity type contact layer
507 epitaxial side electrode
508 substrate side electrode
511 substrate
512 first conductivity type clad layer
513 active layer
514 second conductivity type first clad layer
515 first conductivity type current block layer
516 second conductivity type second clad layer
517 second conductivity type contact layer
518 epitaxial side electrode
519 substrate side electrode
601 n-type GaAs substrate
602 n-type AlGaInP clad layer
603 undoped GaInP active layer
604 p-type AlGaInP clad layer
605 n-type GaAs block layer
606 p-type GaAs contact layer

[Document Name] Drawings

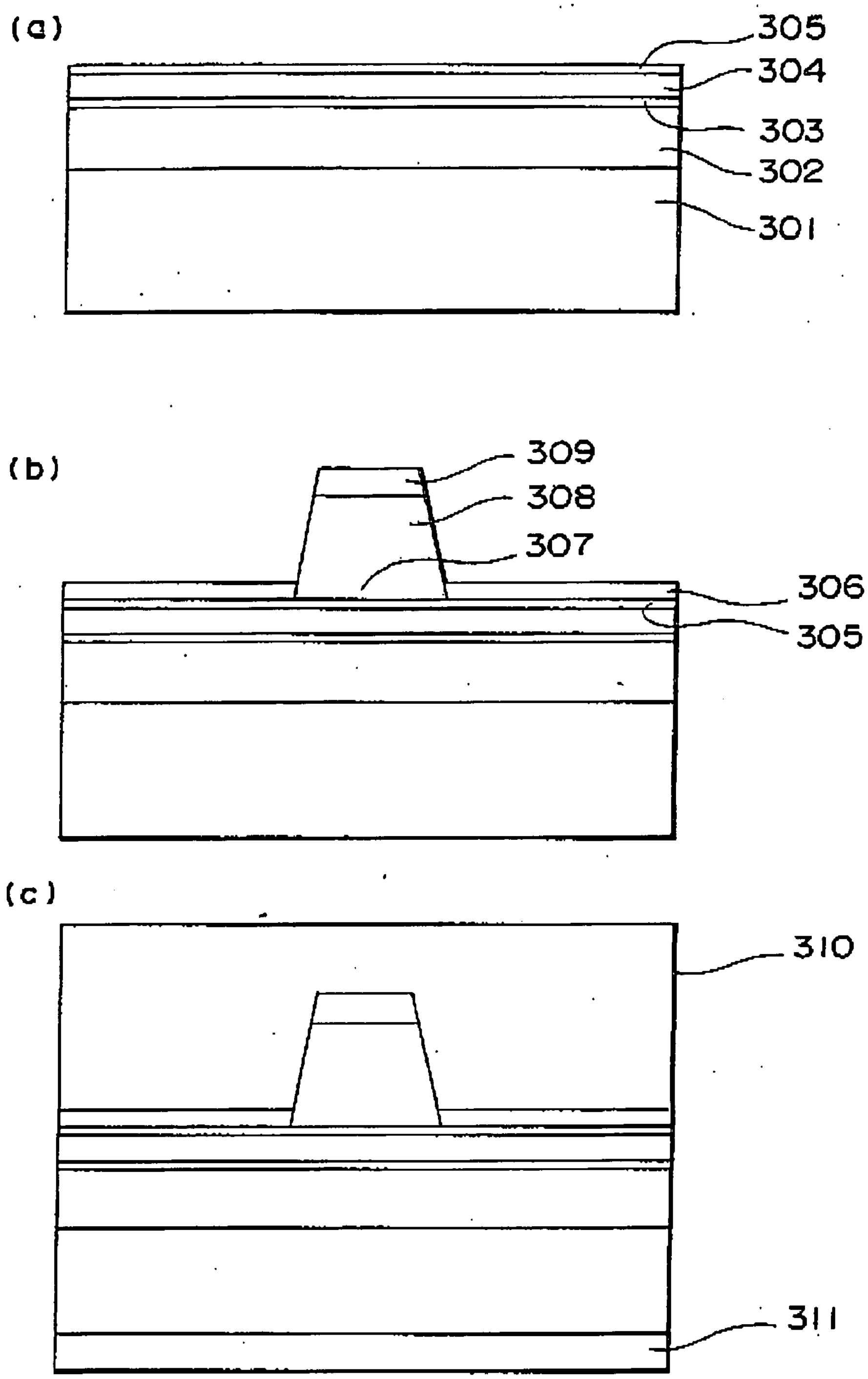
[Fig.1]



[Fig.2]

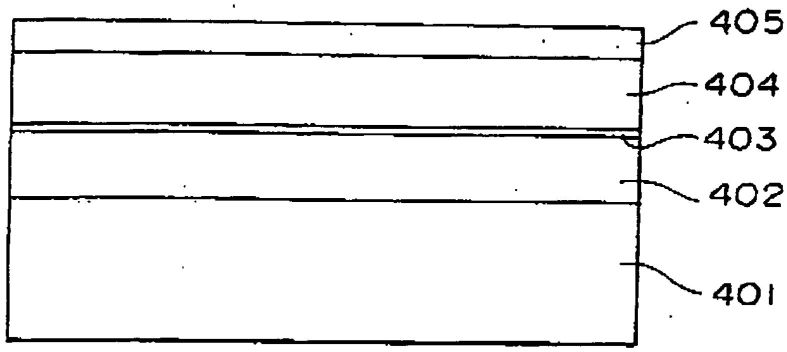

rear facet
W1
W2
front facet
W1
(a)
rear facet
W1
W2
front facet
W1
(b)

[Fig.3]

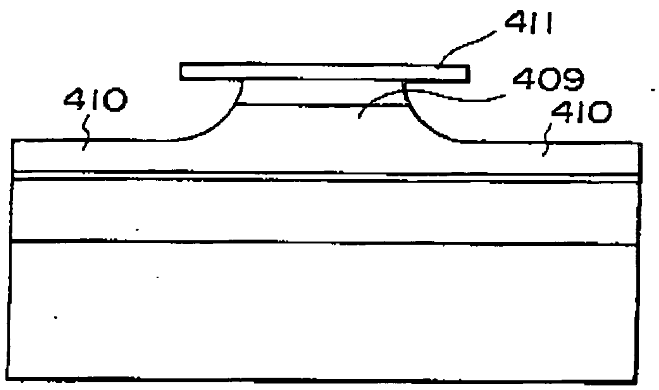


[Fig.4]

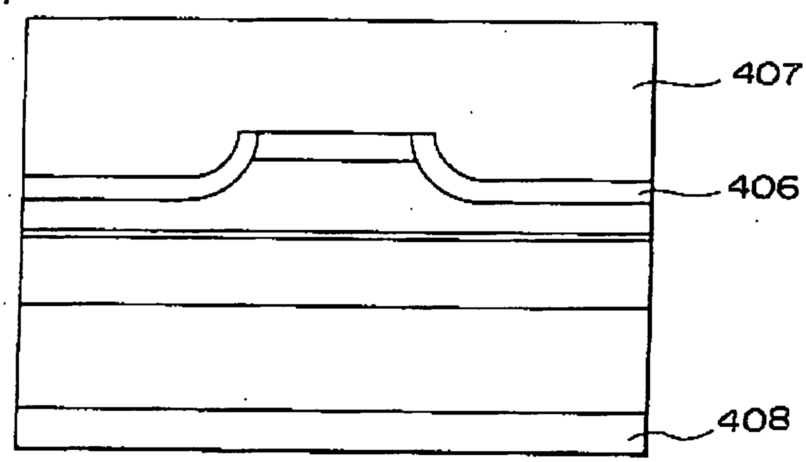
(a)



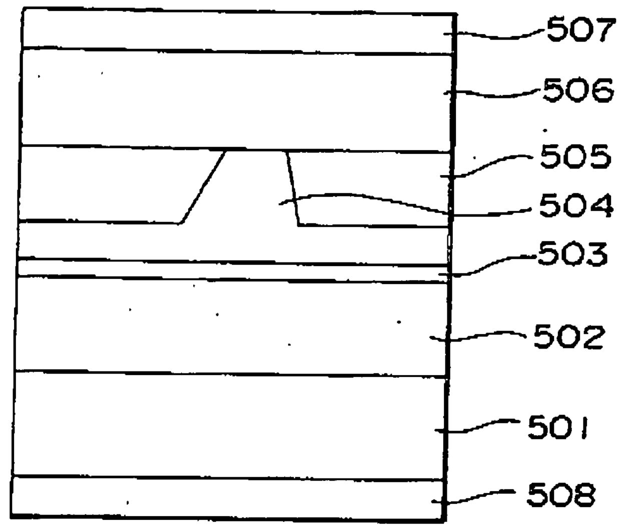
(b)



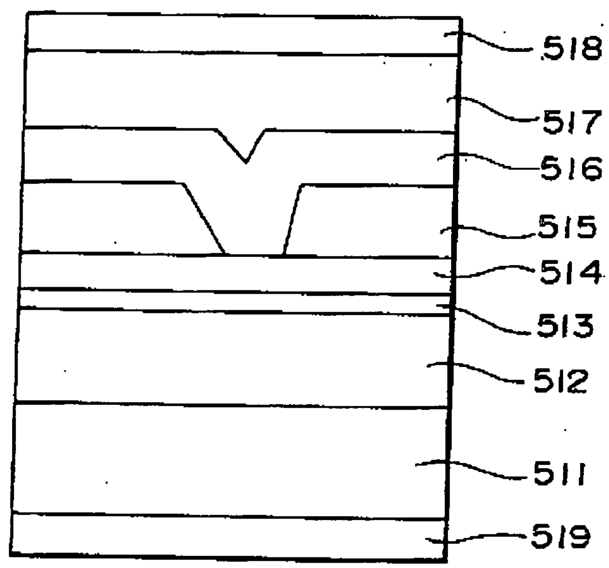
(c)



[Fig.5]

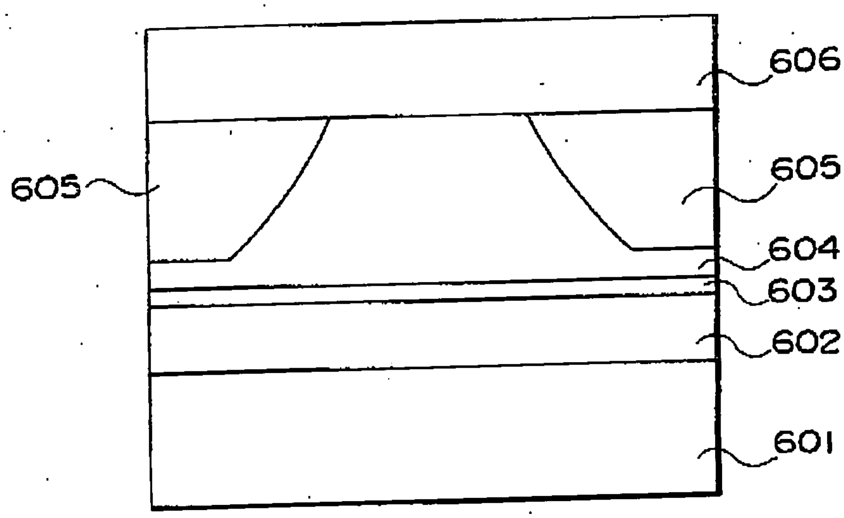


(a) Ridge



(b) Groove

[Fig.6]



[Document Name] Abstract of the Disclosure

[Abstract]

[Object] To provide a semiconductor light emitting apparatus having good controllability and reproduction property of a ridge shape and a compound crystal composition (lattice constant, refractive index, etc.) of a semiconductor layer constituting the ridge, with stable laser property and high reliability of laser operation.

[Means to solve the problems] A semiconductor light emitting apparatus, at least comprising on a substrate: a compound semiconductor layer containing an active layer; a protection film having an opening formed on the compound semiconductor layer; a ridge type compound semiconductor layer having a smaller refractive index than the refractive index of the active layer, the ridge type compound semiconductor layer being formed as to cover the opening; and an electrode formed on the ridge type compound semiconductor layer, and further comprising a layer whose In compound crystal composition is no less than 5%, wherein an In compound crystal composition of the ridge type compound semiconductor layer is no more than 10%.

[Selected Drawing] None